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ABSTRACT

This paper discusses skills science teachers need to effectively use computing in their teaching and describes how pre- and in-service science teachers can acquire computing skills. These skills can be grouped under three headings: (1) computer as a tutor for students (such as using drill and tutorial programs to bolster achievement); (2) computer as a tool for students (such as developing algorithmic solutions to problems in science classes); and (3) computer as a tool for teachers (such as providing computer-based evaluation and feedback). Following a discussion on the rationale for the skills within these categories, a list of eight research and evaluation questions is provided. For example, examining what combination of computer simulations and laboratory activities will maximize student achievement and if student attitudes toward science are influenced differently by computer-based and regular science instruction are proposed as areas in need of research. Problems that need to be considered related to acquiring computing skills include the usual what, where, when, and how concerns of teacher training. To address these problems, materials to support science teacher training in computing need to be developed and training must be organized and delivered in a manner that is cost efficient and effective in altering behavior. (JN)

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# INTEGRATING COMPUTING INTO SCIENCE INSTRUCTION

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# INTEGRATING COMPUTING INTO SCIENCE INSTRUCTION

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Personal observations, sales figures from leading computer companies, and survey reports all show that significant numbers of microcomputers are now available in schools. There is, however, uneveness in the distribution of them -- the well heeled districts have a disproportionate number of computers and secondary schools appear to have them in greater numbers than their middle or elementary school counterparts.

Even though many computers are now being used and many more purchase orders are about to be submitted there are still relatively few computers available. Coupled with the lack of computers is the lack of skill to use them effectively. Of course, you occasionally encounter teachers with computing skills but they are the exception. Even among science and mathematics teachers where prior background may have led to some computer training, or at least receptivity, the picture is still not bright -- most teachers in our schools, including science and mathematics teachers, have almost no computing skills.

If we compare the microcomputer movement with the major curriculum efforts of the recent past we see some striking differences. Consider just the process skill emphasis in science in the 1960's. In this case there was substantial pressure on teachers to incorporate process skills in lessons. Massive textbook alterations occurred and these were accompanied by energetic federal programs in teacher training. But virtually all the pressure was top-down. Somebody at the top -- usually a scientist, college educator, or science supervisor, worked to build enthusiasm for the innovation among teachers who were the ones who would have to implement it. Parents and students weren't even players in these events.

Now consider the differences with introducing instructional computing in schools. The pressure to purchase and use computers in schools is coming from all sides of the teacher -- not just above. Students want to use computers. Parents have accepted the advertised view of the computer as a key tool for success in the future. Business, industry, and government officials see the rapid rise of computing in their worlds and see a need for educational applications. School people do too -- principals, supervisors, and teachers also understand changes in the world and want their schools to address the computing problems. By no means, of course, are these concerns about computing universally held but it is a rare school that has not begun to do something about computing.

There does seem to be value in incorporating computers into instruction. But, until a research base of studies about computing develops we must logically plan present computing use in hopes of creating a desired future. Four major outcomes are usually listed among those that computers should influence if they are available in schools and used.

1. Learning efficiency of students should increase if they use programs appropriate to their objectives. If a school has enough computers for students to interact with, research evidence favors their use. This finding was true for large, main frame computers and is holding for more recent studies with microcomputers (Wise and Okey, 1983).

2. Important outcomes for schools not now emphasized may become more prevelant. Schools have always been taken to task for not emphasizing higher level thinking or activities requiring formal thought. Computers may provide the means to more frequently and effectively pursue these goals. Consider just one possibility. When using a language like LOGO, students progress from using simple commands and actions to complex problems in which the computer compels them to consider the consequences of actions and to make modifications in views.

3. Students should be better prepared for future employment and education if they routinely use computers in their schooling. It seems to be increasingly true that computers are everywhere--department stores, offices, small businesses, manufacturing plants, and hospitals all have computers and need skilled personnel to use them. Those students who are unable to learn and use new skills will have trouble adapting to training, education, and employment opportunities in their futures.

4. Teachers should be able to eliminate some of the drudgery from their jobs. Test development packages, electronic gradebooks, scoring machines, word processors, and data base programs are all computing applications that have the potential to make teaching more efficient and pleasant.

Given the background just described, the task for school districts, colleges, and universities is equipping science teachers with the skills needed to effectively use computing in their teaching. The problem can be set in context by asking two questions.

1. What skills do science teachers need to effectively use computing in their teaching?

2. How can pre and inservice science teachers acquire computing skills?

## Computing Skills for Science Teachers

The problem of selecting skills or outcomes related to computing is no different from deciding on objectives or goals in any curriculum. Primarily the choice of curriculum outcomes is a matter of opinion and not of fact. The list that follows gives the computing skills considered to be important for science teachers. They are divided among skills used with students, by students, and for students. They embrace all areas of a teacher's job ranging from the planning to the evaluation steps. They include some attention to programming ability but not a major emphasis on programming. In fact, the stronger emphasis among the skills is on using existing programs rather than writing new ones. There is also a strong emphasis on out-of-class applications of computers in the materials preparations, evaluating, and record keeping aspects of a teachers job. This is not to suggest that these are the most important applications of computers for teachers but that they presently represent activities most likely to be done with computers in schools given the scarcity of machines and the high level of demand for them.

In order to effectively integrate computers into their classrooms, science teachers need to learn the skills listed in Figure 1.

Computer as a tutor for the student:

1. use drill and tutorial programs to bolster achievement.
2. use computer simulations to provide experiences that supplement science laboratory programs.
3. use computers as tools in development of rational and logical thinking skills.

Computer as a tool for the student:

4. develop algorithmic solutions to problems in science classes.
5. collect, print, and display data from investigations.
6. use programming to assist students in developing solutions to science problems.
7. expand the resources of the classroom and laboratory by accessing data bases.

Computer as a tool for the teacher:

8. provide computer based evaluation and feedback.
9. keep computer based records on pupils and equipment.
10. prepare instructional materials using print and graphic computer software.
11. evaluate and select computer software and hardware for use in science classes.

Figure 1. Computing skills important for science teachers.

The computing skills are categorized as either "for the student" or "for the teacher." Of course the teacher needs to

know them all in order to help students acquire them. A number of the skills don't fit exclusively into the teacher or student categories either. For example, skill #7, accessing data bases, is an ability that will help students. Teachers could use the same ability, however, to gather information for lectures and discussions that would supplement their local resources.

Another computing skill that cuts across the boundary of being either for the teacher or for the student is skill #8, providing computer based evaluation. The teacher can use this skill to print and score tests. But students may also use the skill through interactive tests on the computer that provide them with formative feedback about progress.

The list of skills should not be considered either set or complete. Further analysis of computing needs in science teaching may alter and expand the list. But the skills cover many of the applications of computing that can profoundly affect how science teachers teach and both what and how students learn.

Rationale for the computing skills

Drill, tutorial, and simulation programs are all used to put students in contact with course content and procedures. Programs in the area are growing in number and variety. It is fashionable to lament that there are no really good computer programs but their quality seems not greatly different from that found among other educational media (books, films, laboratories, etc.).

Drills and tutorials have the potential to involve each student in learning. Classroom group instruction is too often characterized by 1 or 2 students interacting with the teacher while 23 other students watch. Intellectual engagement with course content and activities is necessary for learning. Computer drills and tutorials have the potential to increase the involvement of individuals and thereby increase their learning.

Computer simulations provide an instructional vehicle of special value in science. When used to supplement (not replace) interactions with objects and situations they can enrich experience. Dangerous, expensive, and time consuming events can be simulated. Risk taking with no adverse consequences in order to answer "what it" questions can be tolerated. Recent studies show the value of supplementing laboratory experience with computer simulations (Wise and Okey, 1984).

Logical thinking ability may be promoted by computers in several ways. The most common method is probably through programming in which the student attempts to get the computer to carry out tasks through a series of instructions. Failure by the computer to accomplish the tasks causes the student to reconsider the logic of their instructions. Papert (1980) feels that this computer-author interaction provides numerous instances of the stimulation needed to promote growth in logical thinking.

A second way in which logical thinking ability may be promoted is through selection of tutorials and simulations for students to use. The latter almost always address higher level objectives and thus may provide practice in varied science contexts with the abilities that are ingredients in logical thinking ability.

Developing problem solving algorithms, collecting and processing laboratory data, learning programming, and accessing data bases are all computer uses that assist students in learning. Using the computer as a tool is no different from using calculators, laboratory measuring devices, or even film projectors as means of learning. The computer expands or magnifies the ability of students to acquire and process information and may enhance both what and how much can be learned.

Learning programming and developing algorithms are skills that go hand-in-hand. Programming skills are needed to develop algorithms. The algorithms themselves deal with the problems students encounter in science classes. Consider the problem of calculating the number of moles of a substance available in a given amount. Students typically encounter may problems like this. When the computer is available to the class an added dimension to the learning is available. Mole calculation problems are first handled in the conventional way. Then the teacher helps students consider the steps in solving all such problems. From the steps derived (or flowchart), a simple computer program is written to solve any mole calculation problem. The benefit to students is that they first learn to solve the problems from a series of specific instances and then consider the general case and develop a computer program for it.

Equipment to collect laboratory data have always been around. Now devices to directly interface the computer to events allows students to collect temperature, light intensity, or time duration data. Computer programs for statistical analysis are available as well as those to plot and print charts and graphs. Taken together they allow students to quickly acquire and process large amounts of data and leave more time for interpretation and analysis.

The ability to access data bases is probably the newest of the tools available to science teachers. The data bases may be locally created or those developed by federal or private concerns. The data of interest may be information on incidence of diseases, production of chemicals, location of earthquakes, or populations of animals. Students can search, acquire, and process the information in order to answer questions or pose hypotheses about science phenomena. What the data bases provide is a wealth of information beyond that available in any text that widens the scope of course content or objectives typically pursued in science classes.

The teacher needs to learn the skills described previously in order to help students use them. The remaining computing skills are primarily of value to the teacher as a job aid.

Storing, retrieving, administering, and scoring tests are all jobs suitable for computers. All aspects of all testing programs in science are not amenable to computer assistance but much of the work surrounding testing can be eased with their use. By storing pools of test items in computer files teachers can quickly assemble and print tests. If enough computers are available, test items may be administered to students in an interactive mode. Feedback on test performance and recommendations for additional study can be handled by computers as well.

Word processing is probably the most common computer application. Science teachers can use this tool to prepare any printed material they may use. In addition, charts and transparencies for class use may be more easily and better prepared using computers.

Record keeping concerning students and equipment is a chore for most teachers. Electronic grade books can store and weight grades, calculate averages, and prepare printed reports on grades to send to parents. Data base programs are useful in keeping inventories of supplies and equipment. Orders can be prepared based on levels of supplies available.

In addition to the three categories of skills described above the selection of software and hardware is a recurring task for the science teacher. Hardware selection is often chosen along district guidelines but teachers may sometimes influence these. Selection of software is the important task of the two for teachers. Virtually every application already described depends on appropriate software. Writing your own applications software is usually an appealing alternative to purchasing until someone tries to do it. A software package costing $50 can rarely be developed locally for that same cost.

## Research, Development, and Evaluation

In the short run, the selection and implementation of computer applications needs to be done on a rational, thinking basis because few research guides exist. But what R, D, and E efforts could guide decisions about computing for the future?

Research/evaluation questions

Research and evaluation are especially needed to guide successful integration of computing lessons into the regular curriculum. Some of the important questions relate primarily to learning particular science outcomes while others are more generic. A system for organizing and understanding the questions derives from Stake (1967). Stake describes three categories of variables that are influential in research and evaluation--the setting in which events occur (antecedents), the activities taking place (transactions), and the results from the interactions (outcomes). In the case of computing applications in a science classroom, some of these antecedents, transactions, and outcomes are given in Figure 2. These are some of the important variables associated with science classrooms and thus are candidates for

consideration in studies about integrating computing into science teaching and learning.

Research or evaluation questions are generated by relating variables in the different categories. Questions such as these seem important to consider.

1. What combination of computer simulations and laboratory activities maximize student achievement?
2. Does experience developing problem solving algorithms affect formal thinking ability?
3. Are computer simulations similarly effective with students of all age or cognitive ability levels?
4. Does use of computer based instruction promote greater (more sustained) student involvement?
5. Is use of computer data analysis and graphing programs more effective than regular paper and pencil techniques?
6. Are concepts and generalizations learned in varied science contexts through simulations more widely transferrable than those achieved in limited content domains?
7. Is a wider range of course outcomes (more high level objectives) pursued as computer based materials are used?
8. Are student attitudes toward science influenced differently by computer based and regular science instruction?

| ANTECEDENTS | TRANSACTIONS | OUTCOMES |
|---|---|---|
| Student<br>attitudes<br>prior knowledge<br>ability levels<br>thinking ability | Use of<br>drills<br>tutorials<br>simulations<br>problem solving<br>data analysis and display | Cognitive achievement<br>Attitudes toward science<br>Formal thinking ability<br>Problem solving ability |
| Teacher<br>ability<br>training | Time on task (engagement) | |
| Resources for teaching (quality and quantity) | | |

Figure 2. Three categories of variables in classroom teaching and learning.

## Developing and Delivering Training

Most of the foregoing discussion has been associated with the first of the two questions posed early in this paper--what computing skills do science teachers need to be effective? The question of how teachers are to acquire these skills remains.

Problems that need to be considered here include the usual what, where, when, and how concerns of the teacher training.

1. How can inservice science teachers acquire computing skills?

2. How can preservice teachers learn computing skills and the means of integrating them into science instruction?

3. What computing skills should be incorporated into undergratuate certification and what ones should be left for later?

4. Where can computing skills best (most effeciently and effectively) be acquired by inservice science teachers?

Two categories of tasks need to be addressed in order to respond to the questions listed above. First materials to support science teacher training in computing need to be developed. And second, training must be organized and delivered in a manner that is cost efficient and effective in altering behavior.

Development of materials

Three categories of training materials on computing are needed by pre and inservice teachers.

1. Tutorials on the computing skills themselves. Teachers need to learn to program, use word processors, maintain records, analyze and display data, develop problem solving algorithms, and develop computer based evaluation systems. In all these instances modest levels of skill are needed by the teachers before they can use these applications for their own benefit or hope to successfully introduce them to students.

2. Information packages on available instruction programs and data bases. Some small level of skill may be needed by teachers here but the primary need is information. To use data bases the teacher needs to know which ones are available, what kind of information is obtainable, and finally how to acquire it. When selecting instructional programs the advantage falls to the teacher with broad knowledge of what is available in different curriculum areas.

3. Illustrations of the computing skills being used in science classrooms. The most effective way of changing teacher behavior has been shown to be through the use of models (Yeany and Padilla, 1984). Teaching practices can be influenced by providing filmed il-

lustrations of teachers successfully incorporating computing into instruction and a system for analyzing the classroom interactions.

The development effort should be directed toward producing a rich variety of training materials suitable for a range of training environments. Especially to be avoided are materials aimed at some vague level of awareness about using computing in science classrooms. Solid skill development, precise information, and clear models are needed to arm teachers with applicable and valuable skills.

Delivery of training

Colleges and universities should immediately begin to teach prospective teachers computing skills. In the short run, this training needs to be concentrated in special courses for science teachers that deal exclusively and directly with the skills. Over time, such courses will become unnecessary as students acquire these skills through a great variety of courses in their lower school or college level classes. That circumstance does not prevail now and classes dedicated to these skills are essential to educating new science teachers.

Training in computing skills for preservice teachers should not be a major problem -- the numbers are fairly small, the students are concentrated, and only modest budgets are needed to equip college classrooms for the training. The only major impediment to the training is a college faculty themselves sufficiently well trained or cognizant of the computing applications in science. College courses in programing, although important, are insufficient for the task. Computing applications must receive strong emphasis.

Economics dictates that training in computing for inservice teachers be delivered in the schools. The numbers of teachers that need training is so massive that college based inservice classes can provide only a trickle of new talent to a profession that must rapidly and effectively include computing as an ingredient in instruction. By delivering training to teachers in an on-the-job setting they have the opportunity to learn skills and immediately assess their impact.

Instruction for teachers can be organized in a variety of ways. Teachers can work alone. Groups of teachers can organize themselves. Local leadership people can first learn the skills and then multiply their impact by organizing department or district inservice classes.

The best available technology should be used to deliver the computing training to teachers. Skill building tutorials, information about computing, and models of teachers using computing should be delivered with computers, video disk players,

and video tape machines. The instruction should be interactive and built around content and examples familiar to the science teachers. Practice and feedback should be routinely evident with ample opportunities to observe models and then apply the skills to the science classrooms.

There are tens of thousands of secondary school science teachers in the U.S. Adding middle school teachers who specialize in science increases the number substantially. Taking in elementary teachers who have some responsibility for science increases the pool of teachers who potentially need training with computing to staggering dimensions. Small scale, hit and miss inservice efforts will not address a problem of this magnitude. It is inconceivable that the funds to support summer institute training for a group this size are forthcoming from federal or state budgets.

There is immediate need in schools to upgrade skills of science teachers in computing and technology so they and their students can fully participate in the information age. This is especially true in science education where computers can make education more effective and provide experiences with the applications of computers in science (NSF, 1979).

Among the science teachers employed almost none have the skills that allow them to effetively integaarate computing into classroom activities. The result is a science teaching profession ill prepared to provide the kind of science education students need to learn effectively or to prepare for post secondary education and job opportunities.

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